Comprehensive Truck Size and Weight Limits Study

April, 2016

Comparison of Results Report

Final

U.S. Department of Transportation
Federal Highway Administration

TABLE OF CONTENTS

CHAPTER 1 - INTRODUCTION

The purpose of this Comparison of Results Report is to illustrate the results from the USDOT *2014 Comprehensive Truck Size and Weight Limits (CTSW) Study* and compare with results from past truck size and weight studies. This analysis focuses on past studies that have findings somewhat comparable to those from the 2014 CTSW Study in terms of the types of truck size and weight limits, and networks examined and the metrics used to present findings. The revised desk scans conducted for the 2014 CTSW Study contain summaries of the studies included in this analysis as well as many other studies that may or may not lend themselves to a direct comparison of the 2014 CTSW Study findings.

This report includes results between other studies and the 2014 CTSW Study for all five Tasks' Technical Reports: Modal Shift Comparative Analysis; Compliance Comparative Analysis; Highway Safety and Truck Crash Comparative Analysis; Pavement Comparative Analysis; and Bridge Comparative Analysis.

CHAPTER 2 - MODAL SHIFT COMPARATIVE ANALYSIS

2.1 Purpose

In this section, results from the 2014 CTSW Study are compared with results from past truck size and weight studies. The desk scan conducted for the 2014 CTSW Study contain summaries of the studies included in this analysis as well as many other studies that do not lend themselves to a direct comparison of 2014 CTSW Study findings.

Impacts of truck size and weight changes are compared in Modal Shift Comparative Analysis for three areas – shifts in traffic across different truck configurations and between truck and rail; changes in energy consumption and environmental emissions; and potential impacts on highway traffic operations. Differences in findings across the various studies are interpreted in terms of differences in study scope, purpose, geographic scale, scenario vehicles analyzed, networks available to scenario vehicles, and other relevant factors.

2.2 Comparison of Modal Shift Study Findings

The **Table 2-1** compares estimates of mode shifts from eight past studies to estimates from the 2014 CTSW Study. Five past studies estimated percentage changes in VMT that can be compared with percentage changes in VMT for the various scenarios examined in the 2014 CTSW Study. The largest percentage change in VMT was estimated by Bienkowski in a Texas study. The study examined three vehicle configurations, a 97,000 pound tractor-semitrailer; a 90,000 pound turnpike double; and a 148,000 pound turnpike double. The study was limited to several corridors in Texas. Interviews with trucking company officials and other trucking industry experts were conducted which led to assumptions that, within the study corridors,

- LCV approval would affect primarily standard 5-axle tractor-semitrailers;
- 15% of current truck cargo currently hauled by 5-axle tractor-semitrailers would remain in this vehicle class;
- 35% would be transferred to the 97-kip tridem axle tractor-semitrailers;
- 20% would be transferred to the light doubles; and,
- The remaining 30% would become the 138-kip double 53s.

Results for each vehicle were not reported separately, but base case VMT in 5-axle tractor-semitrailers in the study corridors was estimated to be reduced by 31 percent due to shifts to the larger, heavier vehicles.

The next highest traffic shift was estimated in the USDOT’s 2004 Western Uniformity Scenario Analysis. This study examined impacts of allowing uniform LCV weights and dimensions in the western States that currently allow LCVs. Providing such uniformity within the region was estimated to reduce heavy truck traffic by 25 percent. The various vehicle configurations were generally limited to the Interstate System, but in states that currently allow one or more of those configurations to travel off the Interstate System, that same access was assumed to be retained. There was no breakdown in VMT reductions by vehicle class.

Studies in Wisconsin and Montana estimated much more modest reductions in heavy truck VMT associated with changes in truck size and weight limits. An interesting aspect of the Wisconsin study was that it estimated impacts assuming heavier vehicles were restricted from using the Interstate System as well as impacts if that restriction were removed and the heavy vehicles were allowed to use Interstate highways. As can be seen, restricting the heavier trucks from using the Interstate System had a significant impact on estimate traffic shifts. But, even when allowed to use Interstate highways, the greatest reduction in heavy truck traffic was only slightly more than 1 percent for the 98,000 pound tractor semitrailer. A major reason that traffic shifts were lower than for the Western Uniformity Scenario study is that the Western Uniformity Scenario covered a very large region and changes in weights and dimensions thus could benefit interstate moves as well as intrastate moves. The scenario vehicles in the Western Uniformity Scenario were larger as well.

The final past study that estimated changes in truck VMT is dissimilar from the other studies. McCullough examined the issue of diversion of traffic from rail to truck if truck size and weight limits were increased. He did not assume any specific truck configurations, but rather analyzed impacts associated with a hypothetical 10 percent reduction in trucking costs. This was consistent with the reduction is trucking costs estimated for the LCVs Nationwide Scenario in the 2000 CTSW Study. McCullough estimates that diversion of freight from rail to truck would equal about 7 percent of total long-haul (>200 miles) truck traffic. This would be a much smaller share of total truck traffic which is the base for estimating impacts in the 2014 and 2000 CTSW Studies.

The 2014 CTSW Study estimates much lower reductions in truck VMT associated with the scenarios analyzed than did the 2000 CTSW Study. Among the factors accounting for the differences are:

- **Differences in the scenario vehicles** – In general, the increases in size and weight limits analyzed in the 2014 CTSW Study were smaller than those analyzed in the 2000 CTSW Study. While the 2000 CTSW Study included heavier tractor-semitrailers such as those analyzed in Scenarios 1-3 in the 2014 CTSW Study, those heavy tractor-semitrailers were coupled with doubles combinations with 33-foot trailers and gross vehicle weights of 124,000 and 131,000 pounds. Whereas reductions in truck VMT for Scenarios 1-3 of the 2014 CTSW Study were on the order of 1-2 percent, reductions in the 2000 CTSW Study for scenarios with the heavy tractor-semitrailers and the heavy twin 33 combinations were about 11 percent. Most of the diversion went to the heavy twins since it was assumed they could travel from origin to destination and would be used for truckload as well as less-than-truckload shipments.

- **Differences in the scenario networks** – There was a significant difference in assumptions concerning networks available for triples in the 2014 and 2000 CTSW Studies. The 2000 CTSW Study assumed that triples would be granted wide access and would be able to travel from origin to destination. This assumption was based primarily on their ability to make turns which is comparable to a standard tractor-semitrailer. While there was recognition that other factors might affect access decisions, wide access to origins and destinations was assumed for purposes of the study. With wide access, a further assumption was made that triples at 132,000 pounds gross vehicle weight would be attractive to truckload traffic, despite issues with their maneuverability at loading docks and other locations. Assumptions about access and the attractiveness of heavy triples to truckload operators are quite different in the 2014 CTSW Study. With respect to access, triples are assumed to be limited to the Interstate System and other highways on which they currently operate. They may travel approximately 1 mile off that system to access terminals and other points of loading and unloading, but no farther off the designated triples network. These more restrictive access assumptions led to more restrictive assumptions about the type of traffic that would shift to triples. With very restrictive access it was judged that most truckload operators would not find triples an attractive alternative, despite the much higher gross vehicle weight allowed in Scenario 6. Therefore for purposes of the study, use of triples in Scenarios 5 and 6 was limited to less-than-truckload freight. In practice some truckload operators might find ways to make the use of triples economical, but there was no way of estimating the extent and characteristics of usage by truckload operators.

- **Differences in analytical tools and data sources** – The same basic analytical tools used to estimate modal shifts in the 2000 CTSW Study were also used in the 2014 CTSW Study, but significantly better commodity flow data were available for the 2014 CTSW Study. Some improvements in the Intermodal Transportation Inventory Cost (ITIC) model were made between 2000 and 2014, but the basic logic remained the same. The Freight Analysis Framework (FAF) commodity flow database that was used in the 2014 CTSW Study had not been developed when the 2000 CTSW Study was being conducted, however. Instead, data collected through truck stop interviews was the primary source of truck flow data. These data did not allow short haul moves to be analyzed using the ITIC model and long-haul truck data were much more limited than data available from the FAF. Additionally, improved data on VMT by truck configuration, operating weight and highway functional class were available for the 2014 CTSW Study than the 2000 CTSW Study.

Another important measure of modal shift is the magnitude of changes in railroad traffic. Different studies have used different measures of railroad impacts including reductions in ton-miles moved, reductions in car-miles, reductions in railroad net income, and reductions in railroad contribution. In addition, assumptions about whether railroads will reduce rates to prevent traffic from shifting to the larger, heavier trucks are inconsistent. The last column of **Table 2-1** shows various estimates of rail impacts associated with truck size and weight policy changes. Percentage changes vary from 0.1 percent change in rail contribution for Scenarios 5 and 6 in the 2014 CTSW Study to 60 percent change in ton-miles for shifts to turnpike doubles in the Martland study. The range of estimated rail impacts in the other studies is not as great, but results still vary widely. Assumptions in each study account for much of the variation.

Comparing estimated rail impacts in the 2014 and 2000 CTSW Studies, impacts estimated for scenarios in the 2000 CTSW Study are higher than impacts estimated for the 2014 CTSW Study scenarios. Differences in the scenario definitions and the metrics used to present rail impacts explain a major part of the difference. Scenario vehicles in the 2014 CTSW Study generally have lower gross vehicle weights than vehicles in the 2000 CTSW Study and in the case of triples, access assumptions are much more stringent than in the 2000 CTSW Study. As noted above, the two scenarios from the 2000 CTSW Study that include heavier tractor-semitrailers comparable to those in Scenarios 1-3 of the 2014 CTSW Study also include heavy twin trailer combinations that actually are responsible for most diversion in the 2000 CTSW Study scenarios. The LCVs Nationwide scenario in the 2000 CTSW Study that allowed Rocky Mountain doubles, turnpike doubles, and triples was estimated to have by far the greatest impact on the railroads, but there was no comparable scenario in the 2014 CTSW Study. As noted above, another potential explanation for differences in the rail impacts estimated in the two studies is the metric used to present rail impacts. In the 2014 CTSW Study impacts are expressed in terms of rail contribution which reflects both the lost revenue from diverted traffic, but also the reduced cost associated with shipments that are diverted to truck. The measure used in the 2000 CTSW Study is the change in rail car-miles.

The two studies by Martland included heavy tractor-semitrailers similar to those analyzed in Scenarios 1-3 of the 2014 CTSW Study as well as longer combination vehicles similar to those included in the 2000 CTSW Study. The biggest differences between the Martland studies and the two USDOT studies is that percentage changes in Martland's studies reflect only diversion of traffic for rail-competitive commodities, and Martland does not examine the potential of railroads to reduce rates to keep traffic from diverting. The percentage changes reflected in the USDOT studies are based on a much larger portion of all rail traffic than the Martland studies, and railroads are allowed to reduce their rates to prevent diversion of traffic to trucks. Both of these differences would be expected to show higher rail impacts in the Martland studies than the USDOT studies.

The Western Uniformity Scenario Study estimated significantly less rail diversion than either the 2014 or 2000 CTSW Studies. Two factors may account for this difference. First, the Western Uniformity Scenario was regional in scope while the 2014 and 2000 CTSW Studies were nationwide in scope. Thus long-distance freight moves that had origins or destinations outside the West would not have been able to take advantage of the heavier trucks for the entire trip and would be less likely to divert. Second, one or more LCVs already operate in each of the States included in the Western Scenario and thus some freight that otherwise would have been on the railroads has already diverted to the existing LCVs leaving less traffic subject to further diversion under Western Uniformity Scenario Study assumptions.

McCullough's diversion estimates are based loosely on the reduction in transportation costs estimated for the LCVs Nationwide Scenario in the 2000 CTSW Study, and thus should be compared to estimates of diversion associated with LCVs. His diversion estimate is less than half the estimated diversion for the LCVs Nationwide Scenario in the 2000 CTSW Study. The two studies use different metrics and different methodologies which could account for some of the difference.

Table 2-1: Results Compared by Specific TSW Studies

Study	Vehicles and Weights Analyzed k = thousands of pounds	Change in Truck VMT (percent)	Change in Rail Travel (percent)	Analytical Method	Data Inputs
Nationwide Studies					
USDOT, Comprehensive Truck Size and Weight Limits Study (2014)	3S2-88k 3S3-91k 3S3-97k Twin 33s-80k Triples-105.5k* Triples-129k*	(.6) (1.0) (2.0) (2.2) (1.4) (1.4)	(1.1) (1.1) (3.1) (0.1) (0.1) (0.1) ****	Disaggregate / ITIC	FAF, Carload Waybill Sample
USDOT, Comprehensive Truck Size and Weight Study (2000)	3S3-90k; Twin 33s-124k 3S3-97k; Twin 33s-131k RMD-120k; TPD-148k*; Triple-132k Triple-132k	(11) (11) (23) (20)	(5) (6) (20) (4) *****	Disaggregate / ITIC	Survey data, Carload Waybill Sample
Martland, "Estimating the Competitive Effects of Larger Trucks on Rail Freight Traffic", (2007) (impacts on short-lines only)	3S3-97k RMD-110k TPD-148k		(13) (18) (34) ******	Disaggregate / total logistics costs	Synthetic data reflecting truck-rail competitive traffic
Martland, "Estimating the Competitive Effects of Larger Trucks on Rail Freight Traffic," (2010) (impacts on Class 1 railroads)	3S3-90k 3S3-97k RMD-129k TPD-129 TPD-148k Triple-110k		(13) (19) (36) (30) (60) (12) ******	Disaggregate / total logistics costs	Synthetic data reflecting truck-rail competitive traffic
Regional Studies					
USDOT, Western Uniformity Scenario Analysis (2004)	RMD-129k; TPD-129K*;Triple-110k*	(25)	(.02) ******	Disaggregate / ITIC	FAF, Carload Waybill Sample

Study	Vehicles and Weights Analyzed k = thousands of pounds	Change in Truck VMT (percent)	Change in Rail Travel (percent)	Analytical Method	Data Inputs
Cambridge Systematics, Minnesota Truck Size and Weight Project, Final Report, (2006)	3S3-90k; 3S4-97k; 3S3-2-108k; SU4-80k	**	NA	Expert opinion, sensitivity analysis	Truck VMT data, weight distributions
Cambridge Systematics, Wisconsin Truck Size and Weight Study, 2009 (non-Interstate highways only)	3S3-90k 3S3-98k 3S4-97k 8-axle twin-108k SU7-80k 6-axle truck-trailer-98k	(.06) (.18) (.07) (.06) (.01) (.01)	NA	Expert opinion, sensitivity analysis	Truck VMT data, weight distributions
Cambridge Systematics, Wisconsin Truck Size and Weight Study, 2009 (Interstate and non-Interstate highways)	3S3-90k 3S3-98k 3S4-97k 8-axle twin-108k SU7-80k 6-axle truck-trailer-98k	(0.4) (1.2) (0.5) (0.4) (.02) (.04)	NA	Expert opinion, sensitivity analysis	Truck VMT data, weight distributions
Stephens, Impact of Adopting Canadian Interprovincial and Canamax Limits on Vehicle Size and Weight on the Montana State Highway System, (1996)	Various vehicle classes allowed under Canadian Interprovincial and Canamax Standards	(<=3)***	NA	Expert opinion, results from previous studies	Truck VMT data, weight distributions
Bienkowski, The Economic Efficiency Of Allowing Longer Combination Vehicles In Texas (2011)	3S3-97k; TPD-90k; TPD-138k	(31)***	NA	Expert opinion	Truck VMT data, weight distributions
McCullough, Long-Run Diversion Effects of Changes in Truck Size and Weight (TS&W) Restrictions: An Update of the 1980 Friedlaender - Spady Analysis, 2013	NA – 10% reduction in truck costs assumed	7	(8.5) *******	Econometric estimation of cross-elasticities	Aggregate industry costs

Numbers in parentheses are negative.
RMD – Rocky Mountain Double
TPD – Turnpike Double
SU – Single Unit truck

3S3 – Tractor-semitrailer with 3 axles on the tractor and 3 axles on the trailer
NA= not analyzed
*Limited network
** No change in VMT reported, no % change in transport cost savings reported
*** Impacts of specific vehicle configurations on overall truck traffic volumes were not reported.
**** Estimated change in rail contribution, a measure of profitability
***** Estimated change in rail car-miles
******Estimated change in ton-miles
*******Estimated change in net income

2.3 Comparison of Energy and Environmental Impact Findings

Table 2-2 compares findings from studies that have analyzed changes in fuel consumption and CO_2 emissions associated with truck size and weight policy changes. Fewer studies quantified energy and environmental impacts associated with potential truck size and weight policy options than have quantified impacts on modal shift. As with the comparison of modal shifts, differences in study assumptions, scope, and vehicle configurations analyzed affect the relative study findings.

The 2014 CTSW Study estimated changes in fuel consumption, CO_2 emissions, and NOx emissions associated with each scenario. NOx emissions are not included in **Table 2-2** since no other studies quantified impacts on NOx in a way that could be compared with the 2014 CTSW Study results. Changes in VMT estimated in each study are also shown since they strongly influence energy and environmental impacts. Only a single column is shown for changes in fuel consumption and CO_2 emissions because CO_2 emissions vary directly with fuel consumption.

Changes in VMT and in the mix of vehicle classes and operating weights was estimated to reduce fuel consumption and CO_2 emissions by from .5 percent to 1.4 percent compared to base case fuel consumptions and emissions. The greatest impact was for Scenario 3 which had the tractor-semitrailer with the highest gross vehicle weight. Scenarios 4-6 each had savings of just over 1 percent even though changes in VMT varied among those scenarios. Impacts on fuel consumption and CO_2 emissions were estimated to be greater for scenarios considered in the 2000 CTSW Study. As discussed above, scenario vehicles and the way those vehicles were assumed to operate in the two studies were quite different which contribute to differences in the estimated impacts.

Impacts on fuel consumption and CO_2 emissions estimated in the Western Uniformity Scenario Study were consistent with impacts estimated for the LCV scenarios in the 2000 CTSW Study. In both studies estimated reductions in VMT exceeded 20 percent for the LCV scenarios, leading to decreases in fuel consumption and CO_2 emissions of 12 to 14 percent. As for the 2000 CTSW Study, differences in the vehicles analyzed in the Western Uniformity Study compared to the 2014 CTSW Study account for the different impacts.

The Northeast States Center for a Clean Air Future (NESCCAF) conducted a study in 2009 to examine potential ways to reduce truck-related fuel consumption and CO_2 emissions. Vehicle simulation models were used to estimate the fuel consumption and emissions for various vehicle configurations over the same drive cycle. **Table 2-2** shows that LCVs emit substantially less CO_2 than the baseline tractor-semitrailer under the same driving conditions. Since no modal shifts or VMT reductions were estimated in this study, results are not directly comparable to truck size and weight policy studies, but the methodology used in the NESCCAF study was the basis for the methodology used in the 2014 CTSW Study and results highlight the relative reductions in fuel consumption and CO_2 emissions associated with different vehicle classes.

The Wisconsin truck size and weight study estimated the gallons of fuel that might be saved if various alternative truck configurations were allowed to operate. Percentage changes in fuel consumption were not estimated in the study, but the relative savings for the various tractor-semitrailer configurations analyzed in the Wisconsin study are broadly consistent with the relative impacts estimated for Scenarios 1-3 in the 2014 CTSW Study.

Table 2-2: Comparison of Studies that Have Estimated Fuel Consumption Differences among Vehicle Classes

Study	Vehicles and Weights Analyzed k = thousands of pounds	Change in Truck VMT (percent)	Change in Fuel Consumption (percent)	Change in CO_2 Emissions (percent)
USDOT, Comprehensive Truck Size and Weight Study (2014)	3S2-88k 3S3-91k 3S3-97k Twin 33s-80k Triples-105.5k* Triples-129k*	(0.6) 1/ (1.0) 1/ (2.0) 1/ (2.2) 1/ (1.4) 1/ (1.4) 1/	(0.5) (0.5) (1.4) (1.1) (1.1) (1.1)	(0.5) (0.5) (1.4) (1.1) (1.1) (1.1)
USDOT, Comprehensive Truck Size and Weight Study (2000)	3S3-90k; Twin 33s-124k 3S3-97k; Twin 33s-131k RMD-120k; TPD-148k*; Triple-132k Triple-132k	(11) (11) (23) (20)	(6%) (6%) (14%) (13%)	(6%) (6%) (14%) (13%)
USDOT, Western Uniformity Scenario Analysis (2004)	RMD-129k; TPD-129K*;Triple-110k*	(25)	(12.1)	(12.1)
Northeast States Center for a Clean Air Future (NESCCAF 2009)	3S3-97k Twin 33s-97k RMD-120k Triples-120k Turnpike Doubles-137k	NA	(5%)* (10%)* (21%)* (17%)* (25%)*	(5%)* (10%)* (21%)* (17%)* (25%)*
Wisconsin Truck Size and Weight Study (2009) assuming operations on all highways	Twin 28s-108k 3S4-97k SU7-80k 3S3-90k 3S3-98k SU4-2-98K	(0.4) (0.5) (0.02) (0.4) (1.2) (0.04)	240,000 gallons 540,000 gallons 40,000 gallons 450,000 gallons 1,420,000 gallons 60,000 gallons	

Number in parentheses are negative.
RMD – Rocky Mountain Double
TPD – Turnpike Double
SU – Single Unit Truck
* Difference from base case 3S2

2.4 Comparison of Traffic Operations Impacts from Various Studies

Only a small number of truck size and weight policy studies have analyzed impacts of modal shifts on traffic operations. Vehicle characteristics that can affect traffic operations are discussed in the desk scan. As noted in the desk scan, larger, heavier trucks could affect the following aspects of traffic operations – maintaining speed on grades; weaving, merging, and changing lanes; and maneuvering through signalized intersections; and highway capacity and level of service. Each of these may cause additional delay and congestion costs to other motorists. Previous truck size and weight policy studies generally have treated many of these impacts qualitatively but some have estimated potential impacts on delay and congestion costs. In **Table 2-3**, estimates of changes in delay and congestion costs from previous studies are compared to estimates from the 2014 CTSW Study.

Scenarios analyzed in the 2014 CTSW Study were all estimated to have very minor effects on nationwide traffic delay and congestion costs. Changes are measured for the entire traffic stream including passenger vehicles, because all drivers would be affected by increased delay and congestion. Despite the fact that some scenario vehicles are longer and may not perform quite as well as current vehicles, reductions in VMT associated with each scenario were found to lead to small reductions in both delay and congestion costs. None of the scenarios reduced total delay or congestion costs by even 0.1 percent.

Scenarios analyzed in the 2000 CTSW Study were estimated to have slightly greater impacts on delay and congestion costs, primarily because they involved larger and heavier scenario vehicles that caused greater reductions in truck VMT. The largest impact was associated with the 132,000 pound triple trailer combination that was estimated to potentially lead to an 8 percent decrease in delay and congestion. This estimate must be considered within the context of the scenario assumption that triples would be allowed to travel from origin to destination and would thus capture a significant amount of truckload traffic as well as the less-than-truckload traffic that currently is the predominant type of cargo carried in triples.

Reductions in delay and congestion costs were not quantified in the Western Uniformity Scenario Study, but were generally characterized as small decreases.

Studies in Minnesota and Wisconsin estimated the absolute change in congestion costs associated with the truck size and weight policy options they evaluated, but no percentage changes were provided. Relative changes in congestion costs were very much in line with estimated changes in VMT for each scenario vehicle.

Table 2-3: Changes in Congestion Delay and Costs Estimated in Three Previous Truck Size and Weight Studies

Study	Vehicles and Weights Analyzed k = thousands of pounds	Change in Delay (percent)	Change in Congestion Costs (percent)
USDOT, Comprehensive Truck Size and Weight Limits Study (2014)	3S2-88k 3S3-91k 3S3-97k Twin 33s-80k Triples-105.5k* Triples-129k*	(0.02) (0.03) (0.08) (0.08) (0.05) (0.05)	(0.02) (0.03) (0.08) (0.08) (0.05) (0.05)
USDOT, Comprehensive Truck Size and Weight Study (2000)	3S3-90k; Twin 33s-124k 3S3-97k; Twin 33s-131k RMD-120k; TPD-148k*; Triple-132k Triple-132k	(0.2%) (0.2%) (3%) (8%)	(0.2%) (0.2%) (3%) (8%)
USDOT, Western Uniformity Scenario Analysis (2004)	RMD-129k; TPD-129K*;Triple-110k*	Small decrease	Small decrease
Cambridge Systematics, <u>Minnesota Truck Size and Weight Project, Final Report</u>, (2006)	3S3-90k; 3S4-97k; 3S3-2-108k; SU4-80k		($180,000) ($230,000 ($80,000) ($50,000)
Cambridge Systematics, <u>Wisconsin Truck Size and Weight Study</u>, 2009 (non-Interstate only)	3S3-90k 3S3-98k 3S4-97k 8-axle twins-108k SU7-80k 6-axle truck-trailer-98k		($920,000) ($1,890,000) ($850,000) ($490,000) ($80,000) ($60,000)
Cambridge Systematics, <u>Wisconsin Truck Size and Weight Study</u>, 2009 (Interstate and non-Interstate)	3S3-90k 3S3-98k 3S4-97k 8-axle twins-108k SU7-80k 6-axle truck-trailer-98k		($3,400,000 ($11,000,000) ($4,100,000) ($1,650,000 ($90,000) ($260,000)

CHAPTER 3 - COMPLIANCE COMPARATIVE ANALYSIS

3.1 Purpose

The purpose of this section is to compare principal results of the Compliance Comparative Analysis (Task V.D) with other similar studies available in the literature. This involves two main objectives. First, those documents summarized in the revised desk scan that contain quantitative results pertaining directly to enforcement costs and effectiveness (*i.e.*, the main objectives of the 2014 CTSW Study) are identified. Second, the results from each of the selected documents are reviewed and objectively compared with the results of the 2014 CTSW Study. Two types of comparisons are provided: (1) those pertaining to the scenario results; and (2) other CTSW Study results.

3.2 Comparison of Compliance Analysis Results

The Compliance Comparative Analysis (Task V.D) estimates impacts on the costs and effectiveness of truck size and weight (TSW) enforcement for the six 2014 CTSW Study scenarios. **Table 3-1** summarizes the scenario results. The cost comparisons examine changes in personnel costs for each of the six scenarios. The analysis reveals decreases in personnel costs for all six scenarios relative to the base case personnel costs, ranging in magnitude from 0.3 percent (Scenario 1) to 1.1 percent (Scenario 4). The effectiveness comparisons are based on estimated changes in the proportion of underweight vehicle-miles-traveled (VMT) by control vehicles and alternative configurations for four of the six scenarios.

Table 3-1: Summary of Scenario Results for the Compliance Comparative Analysis

Scenario	Change in Enforcement Personnel Costs Relative to Base Case [%]	Expected Impact on Enforcement Effectiveness
1. 3-S2 @ 88K lb. (53')	-0.3	Not analyzed
2. 3-S3 @ 91K lb. (53')	-0.4	Limited impact
3. 3-S3 @ 97K lb. (53')	-1.0	Limited or no impact
4. 2-S1-2 @ 80 K lb. (2 x 33')	-1.1	Not analyzed
5. 2-S1-2-2 @ 105.5K lb. (3 x 28.5')	-0.7	Limited impact
6. 3-S2-2-2 @ 129K lb. (3 x 28.5')	-0.7	Limited impact

Unlike the other task areas of the 2014 CTSW Study, there are no other studies available with which to compare the results of the enforcement costs and effectiveness scenario analyses. The previous USDOT 2000 CTSW Study discussed aspects of TSW enforcement programs, but the scenario analysis applied in that study excluded enforcement costs or effectiveness. This is also true for the follow-on USDOT, Western Uniformity Scenario Analysis. However, this second study appears to recognize this shortcoming by specifically stating that "there is no detailed discussion of regulatory, enforcement, or other implementation issues that would have to be considered before an option such as the Western Uniformity Scenario Study could be implemented" (USDOT 2004, p. I-1).

Two recent regional TSW studies conducted by Cambridge Systematics for Minnesota (2006) and Wisconsin (2009) also exclude enforcement costs and effectiveness from their scenario analyses. Thus, direct comparisons between the results of the 2014 CTSW Study and these analyses are not possible.

3.3 Comparison of Other Results

Despite a lack of directly comparable scenario-based studies in the literature, some of the 2014 CTSW Study's results can be generally compared with those reported in the literature. **Table 3-2** provides these comparisons. In many cases, direct comparisons are difficult due to differences in the approaches and objectives of comparable studies; these differences are briefly noted in the table, but a detailed review and interpretation of the other studies is not included.

Table 3-2 compares measures of the cost and effectiveness of TSW enforcement programs nationwide, referencing results provided in the previous 2000 CTSW Study. Specifically, comparisons are made of the following measures: expenditures on TSW enforcement programs, total nationwide weighings, total nationwide non-weigh-in-motion (WIM) weighings, total nationwide load-shifting and offloading vehicles, nationwide citation rates, and average nationwide cost per non-WIM weighing. These comparisons offer longitudinal (*i.e.*, time series) insights about TSW enforcement program costs, activities, and effectiveness.

Table 3-2 also compares enforcement program effectiveness—measured in the 2014 CTSW Study using WIM data collected at various locations for the control vehicles and alternative configurations—with estimates of overweight trucking that have been reported in the literature using a variety of estimation methods and data sources. Though direct comparisons are not possible, in general, the range of results determined in the 2014 CTSW Study agrees with the range of results reported in the literature.

Table 3-2: Comparison of Results

Current 2014 CTSW Study's Result	Comparable Result
• Total nationwide expenditures on TSW enforcement reported by states range from $432 million to $487 million (in 2011 USD)	• Total nationwide expenditures on truck weight enforcement reported by states in 1995 was approximately $414 million (in 2011 USD[1]) (USDOT 2000)
• Total nationwide weighings in 44 reporting states range from approximately 177 million to approximately 196 million between 2008 and 2012	• Total nationwide weighings reported by states ranged from approximately 105 million to approximately 170 million between 1985 and 1995 (USDOT 2000)
• Total nationwide non-WIM weighings (*i.e.*, fixed platform, portable, semi-portable) in 44 reporting states range from approximately 65 million to approximately 80 million between 2008 and 2012	• Total nationwide non-WIM weighings (*i.e.*, fixed platform, portable, semi-portable) reported by states ranged from approximately 97 million to approximately 124 million between 1985 and 1995 (USDOT 2000)
• Total nationwide load-shifting and offloading vehicles reported by states range	• Total nationwide load-shifting and offloading vehicles reported by states

Current 2014 CTSW Study's Result	Comparable Result
from approximately 275,000 to approximately 383,000 between 2008 and 2012	ranged from approximately 478,000 to approximately 579,000 between 1985 and 1995 (USDOT 2000)
• Nationwide citation rates (weight citations per non-WIM weighing) range from 0.013 in 2008 to 0.010 in 2012	• Nationwide citation rates (weight citations per non-WIM weighing) ranged from 0.007 in 1985 to 0.006 in 1995 (USDOT 2000)
• Average nationwide cost per non-WIM weighing ranges from $6 to $8 between 2008 and 2012 (in 2011 USD)	• Average nationwide cost per non-WIM weighing was approximately $4 in 1995 (in 2011 USD[1]) (USDOT 2000)
• Proportion of underweight tandem axle weight observations at WIM sites ranges from 87 to 97 percent, depending on configuration and location	• 15 percent of large trucks would exceed axle weight limits on a segment of interstate highway where enforcement was not taking place (Grenzeback *et al*. 1988) • 12 percent of tandem axles exceed the federal limit, based on WIM data (Hajek and Selsneva 2000) • 13 percent of tandem axles exceed the weight limit in Vermont (FHWA 2012) • 99 percent of single, tandem, and tridem axle weights for Rocky Mountain doubles and Turnpike doubles comply with static weight limits, based on WIM data collected in the Canadian Prairie Region (Regehr *et al*., 2010) • 15 percent of trucks weighed at fixed weigh scales on interstate highways violate weight laws (Carson 2011) • 30 percent of trucks on scale by-pass routes violate weight laws (Carson 2011)
• Proportion of underweight gross vehicle weight observations at WIM sites ranges from 73 to 100 percent, depending on configuration and location	• 15 percent of large trucks would exceed gross vehicle weight limits on a segment of interstate highway where enforcement was not taking place (Grenzeback *et al*. 1988) • A minimum violation rate of 6 percent exists at fixed weigh scales (*Grenzeback et al*., 1988) • 10 to 20 percent of all combinations are operating overweight without a permit, based on WIM data (TRB 1990) • 10 to 25 percent of trucks are overloaded, according to enforcement personnel (TRB 1990) • 0.6 percent of trucks exceed gross vehicle weight limits at weigh stations (FHWA

Current 2014 CTSW Study's Result	Comparable Result
	1993) • 10 percent of all miles of travel by trucks with three or more axles is attributed to vehicles weighing more than 80,000 lbs. (U.S. DOT, unpublished) • 1 percent of trucks weighed at continuously operated weigh scales violate weight laws (Taylor *et al*. 2000) • 12 to 34 percent of trucks weighed at low enforcement level weigh scales (no definition for "low" provided) violate weight laws (Taylor *et al*. 2000) • The number of overweight vehicles ranged from 2.27 to 3.19 percent on a weigh scale by-pass route under initial conditions, during scale closure, and after scale re-opening, based on WIM data (Strathman and Theisen 2002) • Based on a survey of states, between 0.5 and 30 percent of truck travel is overweight in surveyed states (Straus and Semmens 2006) • Based on a survey of states: 5 of 12 responding states report that less than 5 percent of trucks weighed at weigh stations are overloaded, 3 of 12 responding states report overloaded rates at weigh stations between 5 and 10 percent, 2 of 12 responding states report overloaded rates at weigh stations between 10 and 15 percent, and 2 of 12 responding states report overloaded rates at weigh stations between 20 and 25 percent (Ramseyer *et al*. 2008) • 99 percent of Rocky Mountain doubles and Turnpike doubles comply with static GVW limit, based on WIM data in the Canadian Prairie Region (Regehr *et al*. 2010) • 15 percent of trucks weighed at fixed weigh scales on interstate highways violate weight laws (Carson 2011) • 30 percent of trucks on scale by-pass routes violate weight laws (Carson 2011)

[1]Costs are normalized to 2011 USD using the Consumer Price Index published by the Bureau of Labor Statistics.

3.4 References

Cambridge Systematics.
—2009. *Wisconsin Truck Size and Weight Study.* Madison, WI: Wisconsin Department of Transportation.

—2006. *Minnesota Truck Size and Weight Project.* St. Paul, MN: Minnesota Department of Transportation.

Carson, J.
—2011. *Directory of Significant Truck Size and Weight Research.* Washington, D.C.: American Association of State Highway and Transportation Officials.

Federal Highway Administration.
—2012. *Vermont Pilot Program Report.* Washington, D.C.: Federal Highway Administration.

—1993. *Overweight Vehicles - Permits and Penalties.* Washington, D.C.: Federal Highway Administration.

Grenzeback, L., Stowers, J., & Boghani, A.
—1988. *Feasibility of a National Heavy-Vehicle Monitoring System.* Washington, D.C.: Transportation Research Board, National Research Council.

Hajek, J., & Selsneva, O.
—2000. *Estimating Cumulative Traffic Loads, Final Report for Phase 1.* Washington, D.C.: Federal Highway Administration.

Ramseyer, C., Nghiem, A., & Swyden, D.
—2008. *Investigation of Cost Effective Truck Weight Enforcement.* University of Oklahoma. Oklahoma City, OK: Oklahoma Department of Transportation.

Regehr, J.D., Montufar, J., Sweatman, P., & Clayton, A.
—2010. "Using exposure-based evidence to assess regulatory compliance with productivity-permitted long trucks." *11th International Symposium on Heavy Vehicle Transport Technology.* Melbourne, Australia: International Federation of Road Transport Technology.

Strathman, J., & Theisen, G.
—2002. *Weight Enforcement and Evasion: Oregon Case Study.* Portland, OR: Portland State University.

Straus, S., & Semmens, J.
—2006. *Estimating the Cost of Overweight Vehicle Travel on Arizona Highways.* Phoenix, AZ: Arizona Department of Transportation.

Taylor, B., Bergan, A., Lindgren, N., & Berthelot, C.
—2000. "The importance of commercial vehicle weight enforcement in safety and road asset management," *Traffic Technology International Annual Review*, pp. 234-237. January.

Transportation Research Board.
—1990. *Truck Weight Limits: Issues and Options.* Washington, D.C.: Transportation Research Board, National Research Council.

United States Department of Transportation.
—2000. *Comprehensive Truck Size and Weight Study*. Washington, D.C.: United States Department of Transportation.

—2004. *Western Uniformity Scenario Analysis: A Regional Truck Size and Weight Scenario Requested by the Western Governors' Association.* Washington, D.C.: United States Department of Transportation.

CHAPTER 4 – HIGHWAY SAFETY AND TRUCK CRASH COMPARATIVE ANALYSIS

4.1 Purpose

The purpose of this section is to compare principal results of the Safety Comparative Analysis with other similar studies available in the literature. This involves two main objectives. First, those documents summarized in the revised desk scan that contain quantitative results pertaining directly to enforcement costs and effectiveness (*i.e.*, the main objectives of the current 2014 CTSW Study) are identified. Second, the results from each of the selected documents are reviewed and objectively compared with the results of the 2014 CTSW Study. Two types of comparisons are provided: (1) those pertaining to the scenario results; and (2) other CTSW Study results.

4.2 Comparison of Safety Study Findings

The Safety Comparative Analysis estimates impacts on the costs and effectiveness of truck size and weight (TSW) enforcement for the six 2014 CTSW Study scenarios.

Table 4-1 summarizes the findings of several key crash studies conducted over the last 20+ years. One can quickly see that there are no findings for LCVs, only for single and double combinations. This is because in all the studies there persisted this issue of a lack of sample size and data detail for LCV crashes. A few studies had results for triples or other double combinations, but review of the reports revealed that the sample size of annual crashes was 20 or less. The safety team also opted not to include the findings of the study by Dr. Sowers, as Dr. Dan Blower profoundly critiqued this research.

A first comparison can be made of the internal consistency of the 2014 CTSW Study estimates for singles and doubles. While the rural and urban Interstate rates vary from state to state, the rural Interstate rates are around 0.5 or less for singles, close to the rate for doubles in Kansas. The 2014 CTSW Study did not compute crash rates for doubles in Washington, Idaho and Michigan because it was not part of the scenario to do so. These results are similar to those of Abdel-Rahim using data from some of the same states, but in earlier years. The Western Uniformity Scenario Study has higher rates for both singles and doubles; it is difficult to say why, but that study drew crash data from many more states, so the many state-level differences (e.g., reportability thresholds; data collection practices) may be at play. It is not possible to say much more.

It is more difficult to include the work by Campbell *et al.* in the comparison because the work involves fatal crashes only. The differences with respect to operating environment are generally the same with urban interstates have high rates then rural interstates. So, what can we conclude? The safety team has some reasonably consistent crash rate estimates for doubles and single combinations, but there is virtually no information on LCVs. **Table 4-1** provides yet additional evidence of the need to enhance and fundamentally re-think how we address the safety implications of larger and heavier trucks.

There are really no comparisons to be made for the inspection and violations analysis as no studies of that type were discovered in the literature.

Table 4-1: Synthesis of Previous Studies

Study	Crash Data Source	Exposure Data Source	Findings (Crashes per million vehicle miles)	Comments
Jovanis *et al*., 1989	Fleet records; all crashes	Fleet dispatches for routes with both twins and 3-S2 operations	3S2*: 3.83 Twin*: 3.52	Data from one carrier; all crashes
Campbell *et al*., 1988	TIFA (1980-84)	NTTIS (1985)	Single*: Rural 4.50 Urban 5.80 Double* Rural 4.06 Urban 4.30	From Western Uniformity Study Table VII – 7, Page VII – 17
2014 CTSW Study	Washington (2008-2011)	WIM and FHWA VMT	Single: Rural 0.27 Urban 0.35 Combined: 0.31	Crash frequencies per year range from 85-100 in Idaho, to 270 in Michigan Doubles sample sizes small in Washington, Idaho and Michigan
	Idaho (2008-2010)	WIM and FHWA VMT	Single: Rural 0.47 Urban 0.67 Combined: 0.51	
	Michigan (2008-2012)	WIM and FHWA VMT	Single: Rural 0.19 Urban 0.24 Combined 0.22	
	Kansas Turnpike (2008-2012)	VMT (2008-2012)	Single Rural 0.58 Urban 1.00 Double: Rural 0.46 Urban 0.53	Crash frequencies ranged from 50 to almost 80 per year
Abdel-Rahim *et al*., 2013	Utah (1999-2004)	FHWA and WIM	Singles:0.48 to 0.81 per year Twin: 0.48 to 1.06 per year	Only computed crash rate per year all facilities; no route type breakdown
	Idaho (2003-05)		Single 0.78 to 0.92 Double 0.91 to 1.16	Only computed crash rate per year all facilities; no route type breakdown
Western Uniformity Scenario (1995-99)	Crash data from 13 WUSA States	VMT for study using FHWA VMT	Rural Inter. – 1.50 single 1.83 multi Urban Inter. 2.10 single 1.39 multi	

* Include all crashes for firm, not just DOT reportable

** These rates are fatal involvement rates per 100 million vehicle miles

* Include all crashes for firm, not just DOT reportable

** These rates are fatal involvement rates per 100 million vehicle miles

CHAPTER 5 - PAVEMENT COMPARATIVE ANALYSIS

5.1 Purpose

The purpose of this section is to compare principal results of the Pavement Comparative Analysis with other similar studies available in the literature. This involves two main objectives. First, those documents summarized in the revised desk scan that contain quantitative results pertaining directly to pavement analysis (*i.e.*, the 2014 CTSW Study) are identified. Second, the results from each of the selected documents are reviewed and objectively compared with the results of the 2014 CTSW Study.

5.2 Comparison of Pavement Study Findings

Unlike most other recent truck size and weight studies, the 2014 CTSW Study considered some scenarios that result in anticipated increases in average axle loads and some that resulted in decreases. In the 2000 CTSW Study, all scenarios resulted in significant reductions in average axle loads, as did the 2004 Western Uniformity Scenario Study and state studies in Minnesota and Wisconsin. Only the Vermont pilot study resulted in increases in average axle loads.

As discussed more thoroughly in the pavement desk scan report, the Vermont pilot study and all recent previous federal studies have all used a different approach than was applied in the current CTSW. In each of these studies, pavement performance or design models were used to derive load equivalence factors for various types of pavement distresses and incorporated into specialized national pavement cost models designed to be used for cost allocation and truck size and weight analysis studies.

Most state truck size and weight studies have used a much simpler approach of estimating traditional ESALs for a base case and for each scenario, then applying a cost-per-ESAL-mile estimate to the change in ESALs.

The current CTSW used an approach of applying the most current pavement design model to a small number of pavement sections to directly estimate changes in initial pavement life for each pavement section under each scenario. Initial lives were translated to life cycle costs and expanded to represent the entire highway system.

Differences in the study approaches as well as in the types of scenarios considered render direct comparison of the results of the various studies somewhat difficult, but **Table 5-1** presents summary results from each of these recent state, regional, and national studies. Note that scenarios with lower average axle loads tended to result in reduced pavement costs, while cases with higher average axle loads tended to result in increased costs. Note, however, that some scenarios resulted in somewhat more subtle interactions between reduced VMT and increased average loads per axle. Average axle loads, after all, are not as important as the distribution of axle loads at the higher ends of the axle load range, given the non-linearity of pavement damage as a function of axle load.

Note in **Table 5-1** that the last major national study, the 2000 CTSW Study, used scenarios that resulted in truck VMT reductions of 11 to 23%, while the current scenarios resulted in much more modest overall changes in truck VMT. Note, however, that pavement costs decreased by small amounts for each of the 2000 scenarios, but increased for some of the current scenarios.

Note also that the only previous study that used a pavement design model (MEPDG) similar to the design model used in this study (*AASHTOWare Pavement ME Design*®) was also the only previous study that showed an increase in pavement costs on the Interstate system (and a slight decrease off the Interstate System). It should be noted that the similar design models were applied in very different ways, but still resulted in similar results.

Table 5-1: Summary Pavement-Related Analysis Results

Study	Vehicles and Weights Analyzed k = thousands of pounds	Change in truck VMT	Change in Pavement Costs
Nationwide Studies			
USDOT, Comprehensive Truck Size and Weight Limits Study (2014)	3S2-88k 3S3-91k 3S3-97k DS5 33s-80k TS7-105.5k TS9-129k	-0.6% -1.0% -2.0% -2.2% -1.4% -1.4%	+0.4% -2.4% -2.6% +1.8% +0.1% +0.1%
USDOT, Comprehensive Truck Size and Weight Study (2000)	3S3-90k; DS9 33s-124k 3S3-97k; DS9 33s-131k RMD-120k; TPD-148k; Triple-132k Triple-132k	-10.6% -10.6% -23.2% -20.2%	-1.6% -1.2% -0.2% 0.0%
Regional Studies			
USDOT, Western Uniformity Scenario Analysis (2004)	RMD-129k; TPD-129K; Triple-110k	-25%	-4.2%
WsDOT, Wisconsin Truck Size and Weight Study (2009)	3S3-90k 3S4-97k SU7-80k DS8-108k 3S3-98k SU6-98k	-0.4% -1.2% -0.5% -0.02% -0.4% -0.04%	-$14.6 M -$19.9 M -$1.5 M -$16.8 M -$10.2 M -$0.3 M
FHWA, Vermont Pilot Program Report (2011)	SU3-55k; SU4-69k; CS5-90k; 3S3-99k expanded to Interstate for one year	+1.7%, Int -1.5% Non-I	+12%, Int -0.5%, Non-I
MnDOT, Minnesota Truck Size and Weight Project (2006)	3S3-90k 3S4-97k 3S3-2-108k SU6/7-80k	Not Reported	-$1.3 M -$2.2 M -$1.3 M -$0.6 M

CHAPTER 6 - BRIDGE COMPARATIVE ANALYSIS

6.1 Purpose

The purpose of this section is to compare principal results of the Bridge Comparative Analysis with other similar studies available in the literature. This involves two main objectives. First, those documents summarized in the revised desk scan that contain quantitative results pertaining directly to bridge analysis (*i.e.*, the main objectives of the current 2014 CTSW Study) are identified. Second, the results from each of the selected documents are reviewed and objectively compared with the results of the 2014 CTSW Study.

6.2 Comparison of Bridge Study Findings

6.2.1 Structural Impacts Due to Overweight Trucks

6.2.1.1 Strength Limit State

The results of studies of impacts to bridges in terms of the strength limit state due to overweight trucks have been presented as the dollar value of resulting bridge replacements. Due to the variety of loadings (truck configurations studied), analysis methods used, roadway and bridge networks considered, etc., the direct comparison of reported bridge replacement costs do not yield meaningful results. The limited comparison presented in **Table 6-1** is focused on the scale of study, the analysis approach, and the truck types investigated in two previous studies, compared to the 2014 CTSW Study.

Table 6-1: Major Bridge Study Analyses

Name of Study	**USDOT Comprehensive Truck Size and Weight Study, 2000**	**Wisconsin Truck Size and Weight Study, 2009**	**USDOT Comprehensive Truck Size and Weight Limits Study, 2014**
Scale of study	Used NBI data to screen bridges from 11 states.	85 bridges including 25 slab bridges, 25 pre-stressed girder bridges, 25 steel bridges, and 10 specialty bridges.	500 representative bridges taken from eleven states, representative of the bridges on the national networks and comprised of the twelve most common bridge types spanning from less than 50' to over 500'.
Analysis Approach	Used the WINBASIC program to analyze idealized (not real) bridges and compared results.	Used SEP analysis to record the maximum vehicle weight allowable on the 85 bridges.	Used AASHTO ABrR (VIRTIS) analysis program to conduct LRFR ratings
Types of Trucks	• Base Case • Uniformity Scenario • North American Trade Scenario • Longer Combination Vehicles Nationwide Scenario • H.R. 551 Scenario • Triples Nationwide Scenario • Trucks varied from 3 axle 54 kips GVW up to 9 axle 148 kips GVW	• 6-axle 90 kips GVW • 6-axle 98 kips GVW • 7-axle 97 kips GVW • 8-axle 108 kips GVW • 7-axle 80 kips GVW • (6 axle and Pup with 98 kips GVW)	• 3S2-80 kips Control Vehicle • 3S2-88 kips Scenario 1 • 3S3-91 kips Scenario 2 • 3S3-97 kips Scenario 3 • 2S1-2-80 kips Control Vehicle (28.5' trailers) • 2S1-2-80 kips Scenario 4 (33' trailers) • 2S1-2-2 105.5 kips Scenario 5 • 3S2-2-2-129 kips Scenario 6

Results of 2014 CTSW Study: A threshold Rating Factor (RF) value of 1.0 establishes a potential need for bridge strengthening or replacement. The results are presented in **Table 6-2**.

Table 6-2: 2014 CTSW Study Bridge Results

Number of Bridges in the NBI				LOAD RATING RESULTS in terms of percent of bridges with posting issues (in need of strengthening or replacement)			
# of IS Bridges in the NBI	**# of Other NHS Bridges in the NBI**	**# of IS Bridges Rated**	**# of Other NHS Bridges Rated**	**Vehicle Configuration**	**Vehicle Configuration**	**% of IS Bridges Rated with RF < 1.0**	**% of Other NHS Bridges Rated with RF < 1.0**
45417	43528	153	337	Scenario 1	5 axle, 88 kips	3.3%	5.0%
				Scenario 2	6 axle, 91 kips	3.3%	7.7%
				Scenario 3	6 axle, 97 kips	4.6%	9.5%
				Scenario 4	5 axle, 80 kips LCV, 33' trailers	2.6%	3.0%
				Scenario 5	7 axle, 105.5 kips LCV	2.0%	0.9%
				Scenario 6	7 axle, 129 kips LCV	6.5%	5.6%

The desk scan reveals differences in analysis approach or methodology, etc. that render direct comparisons of structural impacts between the current study and previous ones untenable. The bridge team can note that various other studies included some of the same scenario vehicles. For instance, in the 2000 CTSW Study, the North American Trade Scenario featured a six-axle tractor-semitrailer combination weighing 97,000 lbs. This vehicle is essentially the same as the Scenario 3 vehicle in the 2014 CTSW Study. Similarly the Triples Nationwide Scenario (7 axle triple trailer, 132,000 lb. GVW) is similar to the current Scenario 6 vehicle (tractor with three 28' trailers, 129,000 lb. GVW).Similarly, the 6 axle 90,000 truck and the 6-axle 98,000 lb. truck featured in the 2009 Wisconsin Truck Size and Weight Study correspond fairly closely with Scenarios 2 and 3 of the 2014 CTSW Study. However, differences in analysis method, determination of control or base vehicles, governing threshold criteria, study limits (networks), presentation of results, etc. prevent direct comparison.

6.2.1.2 Bridge Fatigue Limit State

According to the results of the Desk Scan, it can be concluded that actual truck traffic closely correlates the effects of the fatigue design truck and that heavy traffic will not cause severe fatigue problems on steel girders with fatigue details of categories A, B and C. therefore, analysis focused on the categories D, E and E' (E-prime) will be more meaningful. Previous studies on overweight truck effects, have primarily been a product of state sponsored research using limited WIM data in accordance with the state's needs. Due to the variety of study purpose and needs, analysis methods, fatigue trucks, etc., there are not widely available results for direct comparison to the results obtained for the specific scenario vehicles considered in the 2014 CTSW Study. Only the 2003 Minnesota DOT "Effects of Increasing Truck Weight on Steel and Prestressed Bridges", (Altay *et al.*, 2003) study evaluated the effects of increasing the legal truck weight on fatigue details categories E and E'. The results of this study can yield meaningful comparison with the 2014 CTSW Study and detailed compassions are listed in **Table 6-3**.

Table 6-3: Major Bridge Study Results

Study	2003 Minnesota DOT Study	2014 CTSW Study
Fatigue Trucks	• 54 kip Truck (HS15) • 58 kip Truck • 66 kip Truck	• 3S2-80 kip Truck • 3S2-88 kip Truck • 3S3-91 kip Truck • 3S3-97 kip Truck • 2S1-2-80 kip Truck (28.5' trailer) • 2S1-2-80 kip Truck (33' trailer) • 2S1-2-2 105.5 kip Truck • 3S2-2-2-129 kip Truck
Bridge Data	• 4 span continuous bridge (Category E') • 3 span continuous bridge (Category E) • Multiple span continuous plate girder (Category C) • 2 span continuous bridge (Category E')	• Short span (42') simply supported bridge (Category E') • Long span (133') simply supported bridge (Category E) • 3 span continuous bridge (Category E) • 5 span continuous bridge (Category E)
Results	• Bridges that did not have E or E' details had infinite fatigue lives under all situations including a 10% increase in truck weight; bridges with category D or better details and with connection plates attached to both flanges are not as susceptible to fatigue. • An increase in truck weight of 20% would lead to a reduction in the remaining life in these older steel bridges of up to 42% and a 10% increase would lead to a 25% reduction in fatigue life.	• 12% higher main axle weights result in an incremental 25 to 27% negative effect on fatigue life. • The addition of the third axle to the rear axle grouping results in a negative effect on fatigue life on the order of 29 to 54%. • A negative incremental effect on fatigue life will be up to 66% due to the closely spaced axles.

6.2.1.3 Service Limit State

Numerous transportation entities at state and national levels have conducted highway cost allocation studies (HCAS). The scale and breadth of these studies varied from urban settings to highway corridors, to state to region or national levels. Bridge costs were either studied separately or determined as a portion of the overall highway pavement costs as indicated below. Methods and means of conducting the cost studies depended on the purpose of the study and the availability of the data. **Tables 6-4 and 6-5** are presented on the following pages. **Table 6-4** includes HCAS conducted in the United States at national or state levels. **Table 6-5** includes HCAS studies conducted in other countries at national levels. The final costs themselves are not depicted due to the disparity in the cost ranges. This disparity arises not only from the scale of the study, but also methods, purpose of the study, and the composition of the costs. For example would a corridor study devised to determine user fees (tolls) be comparable to a regional study looking for costs attributable to overweight trucks to establish permit fees and fines for violating weight limits. However, the bridge team has provided a listing of the methods, allocators and other parameters used for each study as applicable.

Table 6-4: Highway Cost Allocation Studies (as applied to bridges) (US)

Owner Agency/Year	Scale/Type of Study	Method	% of Cost Attributed To All Trucks	Key Allocators	Axle Load Power	Cost Category
2000 CTSW Study	National Study	Federal	-	VMTs used to distribute cost between truck types	NA	Pavement & Bridges
Arizona/2005	State HCAS	Federal-Hybrid	-	VMT	NA	Pavement & Bridges
Ohio/2009	State HCAS	Federal & AASHTO	35%	ESAL/LEFs	4th	Pavement & Bridges
Oregon/2013	State HCAS	Modified Federal	30%	VMT	NA	Bridges
New York/2013	Corridor HCAS	Federal	NA	WIM	NA	Bridges
District of Columbia/2010	Trucking Routes in City Limits HCAS	Modified AASHTO	41%	ESAL/LEFs	2.9th	Pavement & Bridges
South Carolina/2011	State HCAS	Fatigue Limit State	-	Stress levels in Deck Reinforcement or Pre-stressed Tendons	NA	Bridges
Vermont/Maine Pilot Study/2012	Interstate Corridor HCAS	Fatigue Limit State	-	Stress Levels in Weld Detail C	NA	Bridges

Notes: **AASHTO Method:** the determination of ESAL factors (LEFs) to allocate accrued damage costs to different truck types

Federal/Incremental Method (as defined for bridges): the analysis of determining the cost of constructing bridges at design loadings (AASHTO H & HS Trucks) in 5 T load increments of 15 T, 20 T & 25 T Based on 1997 Federal State HCAS Method as formalized in NCHRP Report 495 (2003).

Federal Method: Variation and Refinement of Incremental Approach

Fatigue Limit State: The allocator is an AASHTO Fatigue Detail Category – (C), or deck reinforcement for which a remaining fatigue life is determined based on stress range in the element detail and the number of repetitions using Miner's Principles

ESAL – Equivalent Single Axle Load & **LEF** – Load Equivalent Factor – Also referred to as the "AASHTO" method

VMT – Vehicle Miles Traveled

Table 6-5: National (Highway) Cost Allocation Studies (Foreign)

Country	Method/Allocator (for Weight Dependent Costs)	Axle Load Power	% Attributed to Bridges	Cost Category
Australia	**ESALs** were used (by way of axle load factors – LEFs) to distribute Highway Costs. Bridge Costs were determined as a portion of total Highway Costs & **PCUs** used to proportion costs between truck types.	4th	15 %	Pavement & Bridge Improvements
Switzerland	ESALS (LEFs)	2.5th		Pavement & Bridge Maintenance Costs
Finland	**ESALs** were used (by way of axle load factors – LEFs) to distribute Highway Costs. Bridge Costs were determined as a portion of total Highway Costs & **VKMs** used to proportion costs between truck types.	4th	25%	Pavement & Bridge Maintenance Costs
Germany – 2 Studies	Game Theory (Known as the Maut Study) ESAL (LEFs)/VKMs (Ministry of Transport)	NA 4th	 15%	Pavement & Bridge Maintenance Costs
Sweden	ESAL (LEFs)/VKM	4th	20%	Pavement & Bridge Maintenance Costs
Netherlands (Dutch Study)	ESAL (LEFs) (Does not separate out bridges)	2nd	NA	Highway & Bridges
UK	Truck Average Gross Mass (AGM)	NA	NA	Bridges

Notes:
PCU or PCE – Passenger Car Units or Passenger Car Equivalents
VKM – Vehicle Kilometers Traveled

6.2.2 Bridge Deck Deterioration, Service File and Preventative Maintenance:

The bridge deck subtask analysis in the 2014 CTSW Study was charged with investigating the potential effects of the proposed alternative configuration vehicles on bridge decks. Secondly, it was to investigate the measures owner agencies can take to maintain and preserve bridge decks and for what costs. The bridge team did not find correlative studies dealing with the effects of specific truck configurations (and loadings) or axle loads in quantitative terms on bridge decks. Therefore, a direct comparison of results with respect to the scenario vehicles cannot be made. However, the findings of the report indicate that more long term empirical research on the combined effects of truck axle loads and adverse climatic effects (such as chloride contamination and chemical attacks) is needed on bridge decks. The research then should be augmented with data-driven predictive deterioration models and life-cycle cost analysis methods.

In general, due to design considerations of reinforced concrete bridge decks, wheel loads were applied to localized areas of the slab to find the controlling loading condition. Studies simulated static or dynamic wheel loads. The variables in these studies were typically with respect to deck thickness, reinforcement size and spacing, girder support spacing, and simulating climatic conditions such as moisture and the long term effects of chloride use in cold climates.

Research studies on bridge decks have not investigated the effect of specific truck configurations or the dynamic effects of multiple wheel or axle configurations on the bridge decks in quantitative terms.